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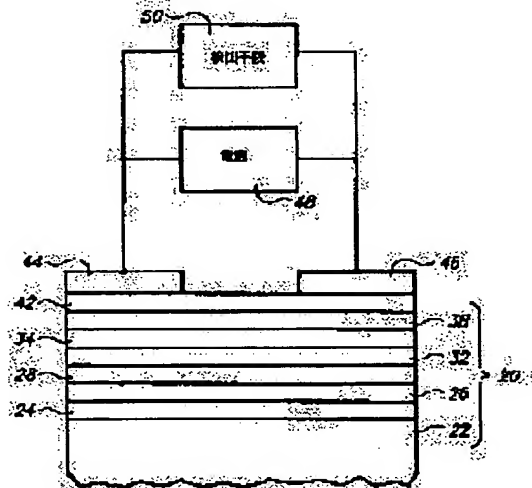
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(54) MAGNETORESISTIVE SENSOR DEVICE

(57)Abstract:

PURPOSE: To obtain a constant field generated by ferromagnetic exchange coupling and a current and thus enable appropriate offset of influence thereof, by additionally providing a magnetic flux keeper layer and a spacer layer in a spin valve structure.

CONSTITUTION: A magnetoresistive sensor 20 has a layered spin valve structure, including first and second thin layers 28, 34 of a ferromagnetic material and separated from each other by a spacer layer 32 of a non-magnetic metal. With a zero-application magnetic field, the direction of magnetization of the first layer 28 is caused to be in parallel to the longitudinal axis of the sensor 20 and perpendicular to the fixed direction of magnetization of the second layer 34. In addition, a thin magnetic flux keeper layer 24 is provided which is separated by the spacer layer 32 and has a fixed direction of magnetization opposite to the direction of magnetization of the second layer 34 and a product of thickness of the substantially same moment as the second layer to offset a static magnetic field from the second layer 34. A power source 48 causes a current to flow via the sensor 20 so as to generate a magnetic field offsetting ferromagnetic exchange coupling between the first and second layers 28, 34. Detection means 50 detects fluctuations in the resistance of the sensor 20 due to the difference in the rotation of magnetic fields of the first and second layers 28, 34.



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CLAIMS

[Claim(s)]

[Claim 1] The magnetic-reluctance sensor equipped with layer-like spin bulb structure has the thin layer of the 1st and 2nd ferromagnetic matter separated by the thin layer of the non-magnetic metal matter. In a zero impression field, the magnetization direction of the 1st above-mentioned layer is substantially parallel to the longitudinal shaft of the above-mentioned magnetic-reluctance sensor, and are substantially perpendicular to the fixed magnetization direction of the 2nd above-mentioned layer. Furthermore, it is separated from the layer spin bulb structure of the above by the thin spacer layer. The magnetic-reluctance sensor which has the thin keeper layer which has the product of the equal moment and thickness in the thing of the 2nd layer substantially in order to offset the static magnetic field from [contrary to magnetization direction of 2nd above-mentioned layer fixed magnetization direction, and above-mentioned] the 2nd layer, So that the field of the sign which offsets the ferromagnetic switched connection between the 1st and 2nd layers of the above, and magnitude may be produced Magnetic-reluctance sensor equipment which has a means to detect fluctuation of resistance of the above-mentioned magnetic-reluctance sensor by the difference of rotation of a means to pass a current in the above-mentioned magnetic-reluctance sensor, and the field of the 1st and 2nd layers of the above, as a function of the field detected.

[Claim 2] Magnetic-reluctance sensor equipment according to claim 1 which it had a substrate, and the above-mentioned keeper layer had high coercivity substantially with the coercivity of the 2nd above-mentioned layer more substantially [it is equal and] than the coercivity of the 1st above-mentioned layer, and has been arranged between a substrate and the 1st layer.

[Claim 3] Magnetic-reluctance sensor equipment according to claim 1 which it had a substrate, and the above-mentioned keeper layer had low coercivity substantially with the coercivity of the 1st above-mentioned layer more substantially [it is equal and] than the coercivity of the 2nd above-mentioned layer, and has been arranged between a substrate and the 1st layer.

[Claim 4] Magnetic-reluctance sensor equipment according to claim 1 whose above-mentioned keeper layer the 2nd above-mentioned layer has been arranged between the 1st above-mentioned layer and the above-mentioned keeper layer, and is made of qualitatively of a magnetic matter in which it has equal coercivity substantially with the coercivity of the 2nd above-mentioned layer.

[Claim 5] It has the 1st and 2nd thin layers of the ferromagnetic matter which is a magnetic-reluctance sensor and was separated by the thin layer of a non-magnetic-material metal. In a zero impression field, the magnetization direction of the 1st above-mentioned layer is substantially [as the longitudinal shaft of the above-mentioned magnetic-reluctance sensor] parallel. Substantially in the fixed magnetization direction of the 2nd above-mentioned layer Perpendicular layer-like spin bulb structure, It is separated from the thin spacer layer of the nonmagnetic matter, and the layer spin bulb structure of the above by the above-mentioned spacer layer. Substantially the magnetization direction of the 2nd above-mentioned layer The reverse fixed magnetization direction, The magnetic-reluctance sensor which has the thin keeper layer substantially made to the thing of the 2nd above-mentioned layer by the ferromagnetic matter with the product of the equal moment and thickness since the static magnetic field from [above-mentioned] the 2nd layer was offset.

[Claim 6] The magnetic-reluctance sensor according to claim 5 which it had a substrate, and the above-mentioned keeper layer had high coercivity substantially with the coercivity of the 2nd above-mentioned layer more substantially [it is equal and] than the coercivity of the 1st above-mentioned layer, and has been arranged between a substrate and the 1st layer.

[Claim 7] The magnetic-reluctance sensor according to claim 5 which it had a substrate, and the above-mentioned keeper layer had low coercivity substantially with the coercivity of the 1st above-mentioned layer more substantially [it is equal and] than the coercivity of the 2nd above-mentioned layer, and has been arranged between a substrate and the 1st layer.

[Claim 8] The magnetic-reluctance sensor according to claim 5 whose above-mentioned keeper layer the 2nd above-mentioned layer has been arranged between the 1st above-mentioned layer and the above-mentioned keeper layer, and is made of qualitatively of a magnetic matter in which it has equal coercivity substantially with the coercivity of the 2nd above-mentioned layer.

[Claim 9] The writing of data, and at least one magnetic storage disk whose reading is possible. The magnetic-reluctance sensor equipped with layer-like spin bulb structure has the thin layer of the 1st and 2nd ferromagnetic matter separated by the thin layer of the non-magnetic metal matter. In a zero impression field, the magnetization

direction of the 1st above-mentioned layer is substantially parallel to the longitudinal shaft of the above-mentioned magnetic-reluctance sensor, and are substantially perpendicular to the fixed magnetization direction of the 2nd layer. Furthermore, it is separated from the layer spin bulb structure of the above by the thin spacer layer. The magnetic transducer which equipped the thing of the 2nd layer with the magnetic-reluctance sensor which has a thin keeper layer with the product of the equal moment and thickness substantially in order to offset the static magnetic field from [contrary to magnetization direction of 2nd above-mentioned layer fixed magnetization direction, and above-mentioned] the 2nd layer, An actuator means to drive the above-mentioned transducer to the above-mentioned disk which is connected to the above-mentioned magnetic transducer and is rotating. So that the field of the sign which offsets the ferromagnetic switched connection between the 1st and 2nd layers of the above, and magnitude may be produced Magnetic storage which has a means to detect fluctuation of resistance of the above-mentioned magnetic-reluctance sensor by the difference of rotation of the field of the 1st and 2nd layers of the above as a function of the field detected from a means to pass a current in the above-mentioned magnetic-reluctance sensor, and the data read in the above-mentioned disk.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to a high performance MAG random access disk unit and the disk unit which specifically has magnetic-reluctance sensor equipment equipped with the spin bulb configuration.

[0002]

[Description of the Prior Art] U.S. Pat. No. 5,159,513 has the publication of the magnetic-reluctance detector using the spin bulb (spin valve) effectiveness. This detector (following sensor) has the multilayer structure of the rectangle to which it adhered on glass or other suitable substrates. This multilayer structure consists of a layer (following fixed bed) magnetization "is fixing" in parallel with the direction of breadth of a sensor by using the layer of the antiferromagnetic substance since the 1st layer is fixed to the "free" layer (below free-layer) of the soft magnetic material matter, and the 1st layer by switched connection, using the hard magnetic-substance matter. A free layer and the fixed bed are separated by the thin spacer layer of non-magnetic metal (for example, copper). Although a free layer is usually magnetized by the longitudinal direction of a sensor, it can also rotate in the transition direction forward with the include angle decided by magnitude of the field under detection, or negative.

[0003] With spin bulb structure, change of resistance is proportional to change of the include angle between the magnetization directions of two magnetic layers (a free layer and fixed bed). Furthermore, change of the resistance of this multilayer structure to a fixed background value is proportional to $\sin \theta$ averaged in the height of a sensor. As mentioned above, θ is the include angle of magnetization of the free layer to the longitudinal shaft of a sensor. Since change of resistance is proportional to $\sin \theta$, the signal acquired by the sensor is linearity through the whole field applied to the small field value. However, if a free layer is magnetically saturated while the applied field is carrying out forward or negative bias movement, a sensor output will become nonlinear and the signal of a peak to the peak which a sensor generates will be restricted.

[0004] The ideal stationary magnetic condition is attained to the whole height of a free layer at the time of $\theta = 0$ for a sensor. An ideal quiescent state is in the furthest condition from magnetic saturation under forward and negative field excitation. A bigger signal output and/or the ideal bias profile which makes max the linearity dynamic range which offers the linearity which improved are generated in the condition. However, this ideal bias profile cannot be attained with the spin bulb structure of an above-mentioned United States patent or a well-known technique. The main reasons an ideal bias profile is not obtained are for the field produced according to the current which flows through magnetic-flux association between the fixed bed and a free layer, and various kinds of layers of spin bulb structure. Although the attempt which offsets such effectiveness which is not desirable by adjusting the direction of a current and putting spin bulb structure on a gap was performed, the bias profile lacking in homogeneity was only obtained by the result.

[0005]

[Problem(s) to be Solved by the Invention] Therefore, it has the magnetic-reluctance sensor element equipped with spin bulb structure, ferromagnetic switched connection and the field generated according to the current are fixed over the whole magnetic-reluctance sensor element, and the magnetic disk memory which these effects can offset appropriately as a result is required.

[0006]

[Means for Solving the Problem] Below, it is separated by the thin layer of the non-magnetic metal matter, and the magnetic-reluctance sensor equipment which has the magnetic-reluctance sensor equipped with the layer-like spin bulb structure of having the 1st and 2nd thin layers of the ferromagnetic matter is described. The magnetization direction of the 1st layer in a zero impression field (zero applied magnetic field) is substantially parallel to the longitudinal direction of a magnetic-reluctance sensor, and substantially perpendicular to the fixed magnetization direction of the 2nd layer.

[0007] The keeper layer with a thin ferromagnetic (keeper layer) is separated from layer-like spin bulb structure by the thin spacer layer. This keeper layer is the product of the equal moment and thickness substantially to the thing of the 2nd layer, in order to have the reverse fixed magnetization direction substantially with the magnetization direction of the 2nd layer and to offset the static magnetic field from the 2nd layer. (moment-thickness product) It has. A current occurs through a magnetic-reluctance sensor and the field of the sign (sign) which offsets the ferromagnetic switched connection between the 1st layer and the 2nd layer, and magnitude is made. Fluctuation of resistance of the magnetic-reluctance sensor by the difference of rotation of the 1st layer and the 2nd-layer magnetization is detected as a function of a field.

[0008] When the 1st layer is between a keeper layer and the 2nd layer, whichever of the ferromagnetic of rigidity or elasticity is sufficient as a keeper layer. A keeper layer must be a hard ferromagnetic when the 2nd layer is between a keeper layer and the 1st layer.

[0009] Drawing 1 is what showed the magnetic profile generated by the magnetic reading head with the spin bulb structure of the above-mentioned conventional technique, and plots the value of $\sin\theta$ to the height of the sensor which begins from an air bearing front face. The magnetization profiles A and B show the magnetization profile generated between forward [under detection of the magnetization transition on a disk], and negative excitation, respectively. The central line C shows the stationary bias condition, and shows the optimal magnetic profile. A free layer begins to be saturated with the polar specific point of ***** of excitation, i.e., the place of $\sin\theta=1$.

[0010] Drawing 2 is what showed the transfer curve of the spin bulb sensor of drawing 1, and plots the average of change of $\sin\theta$ to the field under detection. Before saturation starts, as for this configuration, $\sin\theta$ of fluctuation of a peak to a peak becomes max by 0.77. The curve became nonlinear suddenly, when saturation started, and the signal of a peak to a peak was restricted.

[0011]

[Example] The magnetic disk memory 10 by this invention which has the magnetic disk 11 which is supported by the spindle 12 and rotates by the disk drive motor 13 is shown in drawing 3. The combined head 14 of magnetic-induction writing and magnetic-reluctance reading is attached so that it may move to a disk side with an actuator means, and they write the magnetic data of the truck on a disk. [reading and] An actuator means moves a disk top for a head 14 to a radial through an actuator arm 16, a voice coil motor 15, a suspension 17, and a slider 18.

[0012] The combined head 14 has the rectangular magnetic-reluctance sensor element 20, as shown in drawing 4. The magnetic-reluctance sensor element 20 is rigidity (for example, CoCr), or makes the magnetic-flux keeper layer (flux keeper layer) 24 of the ferromagnetic (for example, NiFe) of elasticity, the spacer layer 26 of the nonmagnetic matter (for example, Ta), and the free layer 28 of the ferromagnetic (for example, NiFe) of elasticity adhere on glass, a ceramic, or the suitable substrate 22 of semi-conducting material. The easy direction of magnetization of the free layer 28 is the direction of an arrow head 30 along the long side of a sensor element. However, the magnetization direction of a layer 28 may be rotated in the forward or negative transition direction from the easy direction of magnetization with the include angle by the magnitude of the field under detection.

[0013] By the spacer layer 32 of the non-magnetic metal matter (for example, copper), the free layer 28 and the fixed bed 34 are separated. The magnetization direction of a layer 34 is being fixed in parallel with the direction of the dimension (namely, short dimension) of the height of the sensor element 20 by switched connection with the layer 38 of the antiferromagnetic substance (arrow head 36). In this case, the coercivity of the keeper layer 24 is substantially [as the coercivity of the fixed bed 34] equal, and should be substantially made higher than that of the free layer 28. However, a layer 34 is the quality of a magnetic matter hard enough, or a layer 38 may be lost if the anisotropy of only being able to hold magnetization high enough is during condition switch actuation. In this case, the coercivity of the keeper layer 24 must be substantially [as the coercivity of the free layer 28] equal, and must be substantially lower than that of the fixed bed 34.

[0014] The sensor element 20 mentioned above is fundamentally [as the sensor element of the United States patent of point **] the same except the point of having added the keeper layer 24 and the spacer layer 26 to spin bulb structure.

[0015] In this invention, the magnetic keeper layer 24 has the magnetization direction contrary to the magnetization direction of the fixed bed 34, and an equal is chosen as substantially [the product of the moment and thickness] as it of the fixed bed 34. A layer 24 carries out the duty of the keeper layer which maintains the MAG to the saturated fixed bed 34, and offsets the static magnetic field from the fixed bed.

[0016] The ferromagnetic switched connection between the free layer 28 and the fixed bed 34 is ***** as the effective field of the direction same on a free layer as magnetization of the fixed bed.

[0017] The sign of the current from a power source 48 (drawing 5) is chosen so that the field may be generated in the free layer 28, and this exchange field is offset. Therefore, as illustrated, a current must be the direction of an arrow head 40 so that the ***** field may become the reverse of the direction of the effective ferromagnetism exchange field on the free layer 28. It depends for the magnitude of the field from a current on the location/arrangement of the sensor element 20 put on the gap between the usual magnetic shielding (not shown) which makes min effectiveness of the stray flux which reduces the magnitude of a current, and the resolution of a rereading signal. In order to generate the degree of the request which offsets the effective exchange field, it can adjust combining the magnitude of a current, and the arrangement location of a sensor element appropriately.

[0018] Since the static magnetic field from the fixed bed 34 is offset by the keeper layer 24 and ferromagnetic exchange and the detection current field are also offset, on it, the ***** effective bias field does not exist in the free layer 28. Therefore, the free layer 28 is uniform and the condition that there is no bias (namely, substantially bias of include-angle zero) is attained. Consequently, before carrying out magnetic saturation of the sensor element 20, it drives by big excitation from a magnetic disk 11, and thereby, it can offer the signal of a peak to a big peak by the magnetic-reluctance sensor of the conventional technique rather than possible.

[0019] With the sensor element 20 shown by drawing 4, as the keeper layer 24 adjoins the substrate 22 and was mentioned above, either the ferromagnetic of elasticity or a hard ferromagnetic is OK as the keeper layer 24. By the field from the current of the direction of an arrow head 40, the keeper layer of a soft magnetic material is saturated in a magnetic-flux close configuration (flux closed configuration) with the fixed bed 34. However, on the other hand,

if a keeper layer is the hard magnetic substance, as shown in the arrow head 41 of drawing 4, a keeper layer must have the magnetization direction contrary to the magnetization direction of the fixed bed. The magnetic substance relates to remnant magnetism (M_r), although elasticity or rigidity is a relative difference whether to be easy to change the magnetization direction of the magnetic substance and is the anisotropy field (H_k) of the matter, coercivity (H_c), and fewer degrees fundamentally. It is a permanent magnet fundamentally, and the hard magnetic substance has high coercivity and its anisotropy field is also comparatively high. On the other hand, the anisotropy field also has [the magnetic substance of elasticity] low low coercivity. The amount of remnant magnetism of a certain matter can be defined for the purpose of the matter in a desired application. Although the hard magnetic substance can have a certain amount of amount of remnant magnetism, even if the magnetic substance of elasticity cannot have remnant magnetism or can have it, it is very slight.

[0020] As shown in drawing 5, it adheres to the cap layer 42 of the high resistance matter (for example, Ta) on the antiferromagnetic substance layer 38 of the magnetic-reluctance sensor element 20. Next, the electric drawer sections 44 and 46 are made on the cap layer 42, and the circuit between the magnetic-reluctance sensor element 20, a power source 48, and the detection means 50 is formed.

[0021] A current flows through the magnetic-reluctance sensor element 20 from a power source 48, and the field of the magnitude which offsets the ferromagnetic switched connection between the free layer 28 and the fixed bed 34, and strength occurs. as the function of a field with which the detection means 50 is detected — the free layer 28 and the fixed bed 34 — fluctuation of resistance of the magnetic-reluctance sensor element 20 by the difference of rotation of each magnetization is detected.

[0022] Sensor element 20 of another somatization of this invention is shown in drawing 6. Here, the keeper layer 24 and the spacer layer 26 are separated and located from the substrate 22 (not being contiguity). In this case, since the current of the direction of an arrow head 40 generates the field of the same direction as the magnetization direction of the fixed bed 34 in the keeper layer 24, the keeper layer 24 must be appropriately fixed so that the magnetization of an opposite direction which is the matter which is the coercivity of the fixed bed 34 and hard magnetic-substance matter (for example, CoCr) which has the same coercivity substantially, or has a high anisotropy, or opposes this field may be held. In this somatization, the cap layer 42 is placed between the keeper layer 24 and the drawer sections 44 and 46.

[0023] Drawing 7 shows the transfer curve of a magnetic-reluctance sensor element with the spin bulb structure in both above-mentioned somatization. This curve is what plotted the average of $\sin\theta$ to the detected field, and shows that the maximum of signal change of a peak to a peak improved from 0.77 (the conventional technique shown in drawing 2) to 1.02. On the air bearing front face of the disk equipped with the shielded spin bulb, it was proved that average $\sin\theta=1$ was the best thing which can be attained. Although somatization with the magnetic disk memory equipped with one disk was shown by the above in order to simplify explanation, shape can be taken also with equipment equipped with two or more disks.

[0024]

[Effect of the Invention] This invention adds a keeper layer and a spacer layer to spin bulb structure, and drives them by excitation from a magnetic disk with a big sensor element by this, and with the conventional technique, the magnetic-reluctance sensor equipment which offers signal change of a peak to a bigger peak, and the high performance magnetic disk drive which used it are offered rather than possible.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The curve of the magnetization profile of the spin bulb structure of the conventional technique.

[Drawing 2] The transfer curve of the spin bulb sensor of drawing 1 .

[Drawing 3] Magnetic disk memory which materialized this invention.

[Drawing 4] Perspective drawing showing one configuration of the magnetic-reluctance sensor of this invention somatization.

[Drawing 5] Magnetic-reluctance sensor equipment with the sensor of drawing 4 .

[Drawing 6] Perspective drawing showing another magnetic-reluctance sensor configuration of this invention somatization.

[Drawing 7] The transfer curve obtained by the spin bulb sensor constituted by this invention.

[Description of Notations]

10 Magnetic Disk Memory

11 Magnetic Disk

12 Spindle

13 Disk Drive Motor

14 Reading / Dictation Combined Head

15 Voice Coil Motor

16 Actuator Arm

17 Suspension

18 Slider

20 Magnetic-Reluctance Sensor Element

22 Substrate

24 Magnetic-Flux Keeper Layer

26 32 Spacer layer

28 Free Layer

34 Fixed Bed

38 Antiferromagnetic Substance Layer

30, 36, 40, 41 The magnetization direction

42 Cap Layer

44 46 Drawer section

48 Power Source

50 Detection Means

[Translation done.]

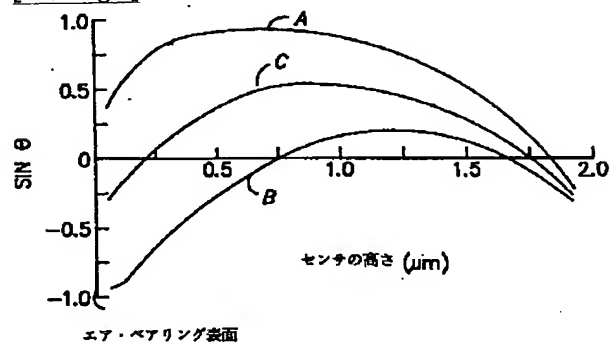
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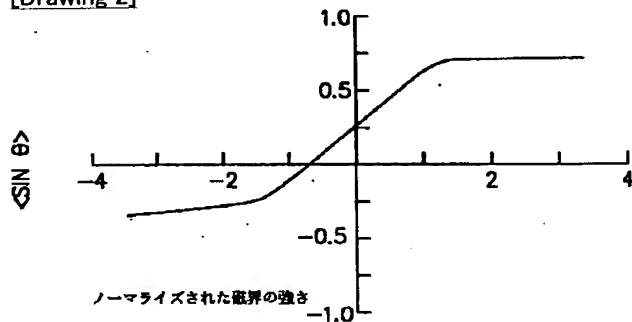
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DRAWINGS

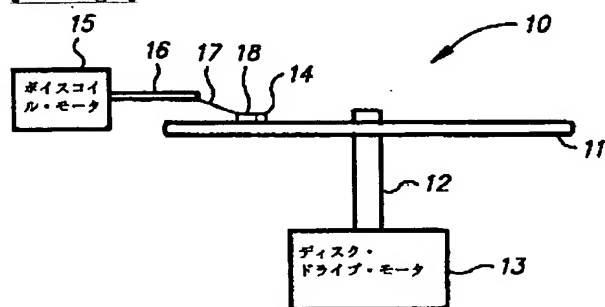
[Drawing 1]



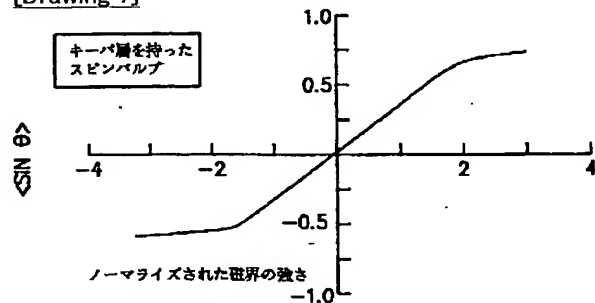
[Drawing 2]



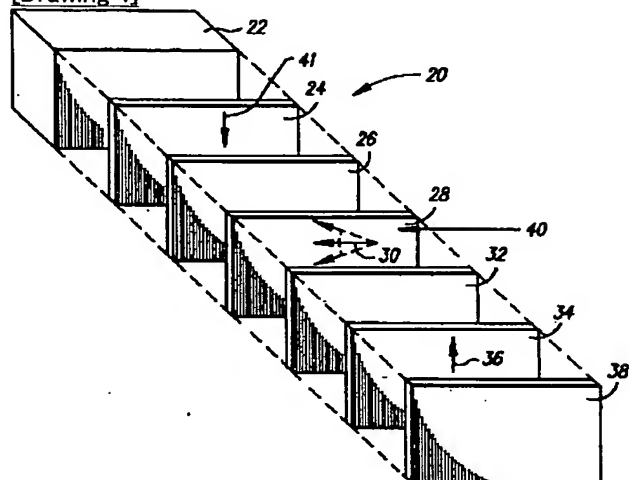
[Drawing 3]



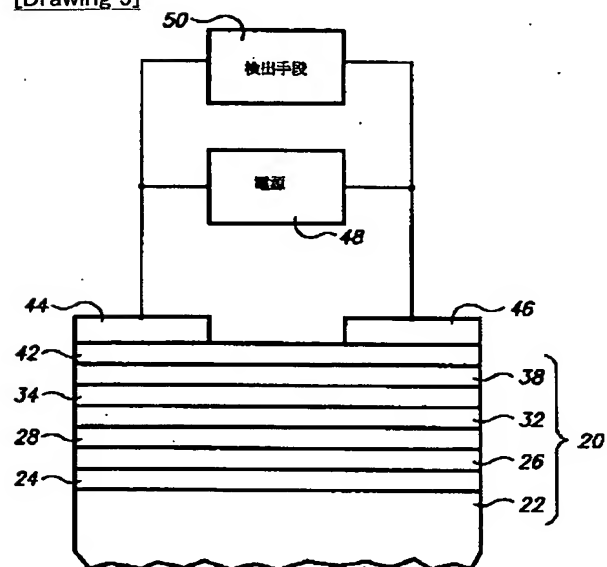
[Drawing 7]



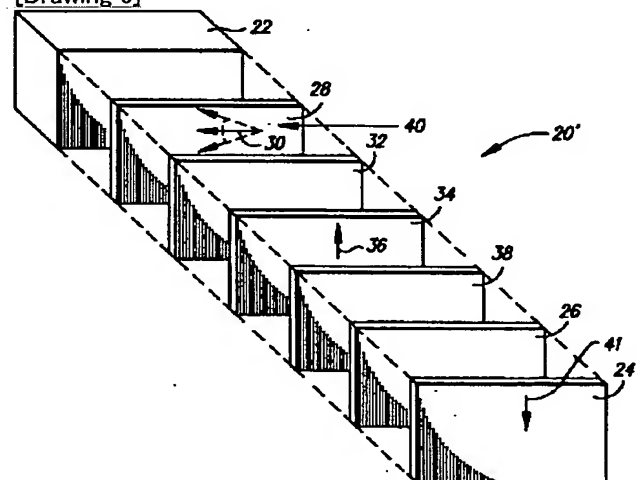
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Translation done.]